RESEARCH FOUNDATION
RESEARCH FOR THE NFPA MISSION

PROJECT SUMMARY

Review of Oxygen Reduction Systems for Warehouse Storage Applications – Phase 2

12 August 2020

Background: Oxygen reduction (or hypoxic) systems are being used in warehouse facilities as an alternative to sprinkler protection. The basic principle of operation is to displace the ambient oxygen in an enclosed environment with one or more nitrogen generators. Two test methods that are available today to determine the reduced oxygen level needed for property fire protection purposes are described in the following documents:

- VdS 3527, *Oxygen Reduction Systems Planning and Installation*
- British Standards Institution PAS 95 (BSI PAS 95), *Hypoxic Air Fire Prevention Systems*

Due to concerns with the current test standards and the application to the real-world scenarios in warehouse storage applications, the Research Foundation completed a project to review literature on the topic and identify research needs. The research revealed that the test methods may not be sufficient for real-scale scenarios and may result in oxygen concentrations too high to prevent ignition and more research is needed on ORS test methods with a specific focus on:

- Data on real-world scenarios with the systems including information on reliability and maintenance issues.
- Full- or real-scale validation of test methods that considers multiple types of ignition sources such as radiative and electrical high energy arc.
- Data on ignition potential based on material type and storage arrangement for different O_2 concentrations.
- Further research on the required oxygen concentration for specific fuels and applications.

Research Goal: Develop both a prescriptive and performance-based design approach to select design oxygen concentrations for oxygen reduction system installations in warehouse applications.

Project Tasks:

Task 1 Prescriptive methodology

Task 1.1. Perform additional large-scale testing and lab-scale testing (fire propagation apparatus) that will consider the following:

- Fuel geometry with emphasis on reduced flue space such as ASRS storage
- Additional materials such as different plastic containers
- High moisture content (MC) conditions such as those typical to commercial freezer operations.

1 Batterymarch Park, Quincy, MA 02169-7471
Telephone: +1.617.984.7281 Fax: +1.617.984.7010
Email: Foundation@NFPA.org www.NFPA.org/Foundation

Tasks 1.2. Material Testing in CACC

Xin and Khan have performed experiments at FM Global to determine the limiting oxygen concentration for ignition of various materials in the fire propagation apparatus (FPA). Zhou and Xin, in a report published by FM Global, have also performed full scale tests on cartoned unexpanded plastics, cartoned expanded plastics, uncartoned unexpanded plastics, and uncartoned plastics. In addition, VdS 3527 and EN 16750 give the ignition threshold oxygen concentration for different materials. A selection of these materials will be tested in the controlled atmosphere cone calorimeter (CACC) to determine the limiting oxygen concentration for ignition at different irradiance levels in order to obtain data with a test method which is more accessible globally. A comparison between the results will be made between the results in CACC and the other test methods.

Task 1.3 – Investigation for an intermediate system screening test

Large-scale tests require a large geometry test set-up that can handle a large amount of combustion products and a considerable amount of nitrogen to run the test in the specified oxygen environment. A test with smaller dimensions but still considering the geometry characteristics as well as combination of materials could be an alternative the reduce the testing resources/costs. This task will develop a screening test set-up and conduct tests to compare to the large-scale FM Global test method.

Task 2. Development of a performance-based design framework for specific applications

Task 2.1. Mapping of the ignition sources typical for warehouse applications

Map credible ignition sources for warehouse applications. Complete a literature review to determine the credible ignition sources using publicly available reports, such as the NFPA report Structure Fires in Warehouse Properties. Reach out to industry to collect this data by means of a questionnaire.

Task 2.2. Behavior of these ignition sources at reduced oxygen levels

The ignition sources which were mapped and defined in task 2.1 will behave differently at reduced oxygen levels. In this task their behavior will be determined by means of literature data and by means of experiments. A priority list for the testing will be made after task 2.1. This task will result in data of how ignition sources will behave at lower oxygen levels with respect to e.g. heat release rate, temperature, smoke production, duration, etc.

Task 2.3. How to replicate these ignition sources in a test environment

From the priority list guidance will be given on how to use the different ignition source in a test environment or how they can be replicated by a selected smaller number of ignition sources.

Task 2.4. Determination of type of configurations and material selection

In warehouses there are different configurations on how materials and product are stored which can affect the fire behavior. The types of materials are also very different from application to application. A selection of most common materials and configuration shall be made based on literature review and using a questionnaire for industry.

Task 2.5. Storage configurations with different geometry and reduced flue spaces.

A very specific configuration is present when there are warehouses with automatic storage retrieval systems (ASRS). In ASRS configurations, the flue spaces can be a lot smaller than in regular storage arrangements. Develop a test set-up with smaller flue spaces to investigate if the flame spread is much different compared to traditional set-ups such as rack storage facilities. Other complex or odd storage configurations may also be considered depending on panel input and the results from previous testing.

Task 2.6. Testing with the specific applications set-up and chosen ignition scenario as well as comparing the results with small scale test(s)
From the previous tasks conducted a selection shall be made of 3-4 specific application set-ups and ignitions scenarios to test as a system (intermediate scale testing). The choice of the systems shall be part of a discussion in the project group in cooperation with the technical panel and the outcome of Task 1.1. Also, as part of this task different small-scale tests shall be run to investigate which of them correspond best with the chosen systems. Typical tests will be the test in the VdS standard as well as FPA and controlled atmosphere cone calorimeter (smaller scale testing).

Task 2.7. Finalization and decision on framework for performance-based design including description of the methodology and necessary tests methods
The final task will develop a procedure and framework on how to apply a performance-based design for a specific application and what type of test could be used to determine the level of oxygen suitable for a specification application with a defined risk level.

Implementation: This research program will be conducted under the auspices of the Research Foundation in accordance with Foundation Policies and will be guided by a Project Technical Panel who will provide input to the project, review periodic reports of progress and research results, and review the final project report.

Schedule: A final report that includes the findings from all tasks will be published in September 2022.

About us:

About the Fire Protection Research Foundation
The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

About the National Fire Protection Association (NFPA)
Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission. All NFPA codes and standards can be viewed online for free.
NFPA's membership totals more than 65,000 individuals around the world.